

Optical Frequency Domain Visualization of Electron Beam Driven Plasma Wakefields.

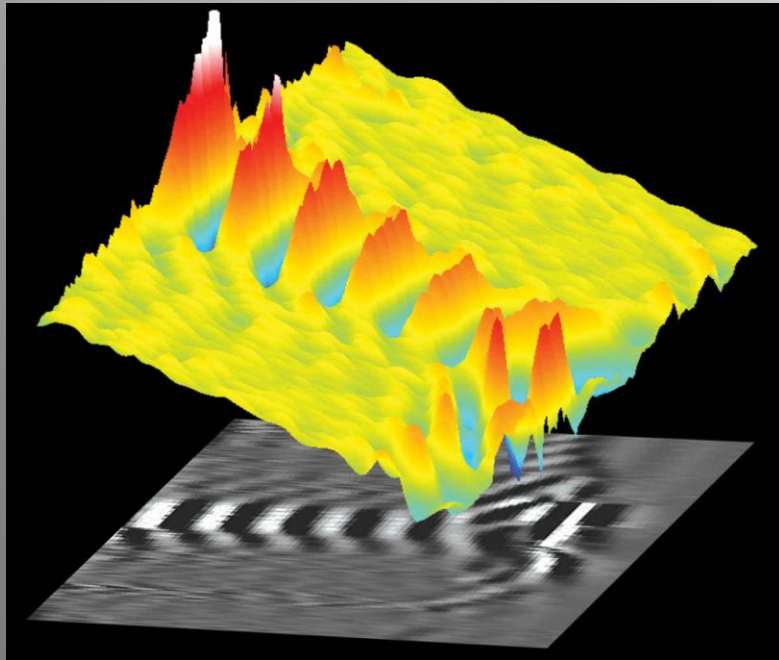


Rafal Zgadzaj, Michael C. Downer, (UT Austin)

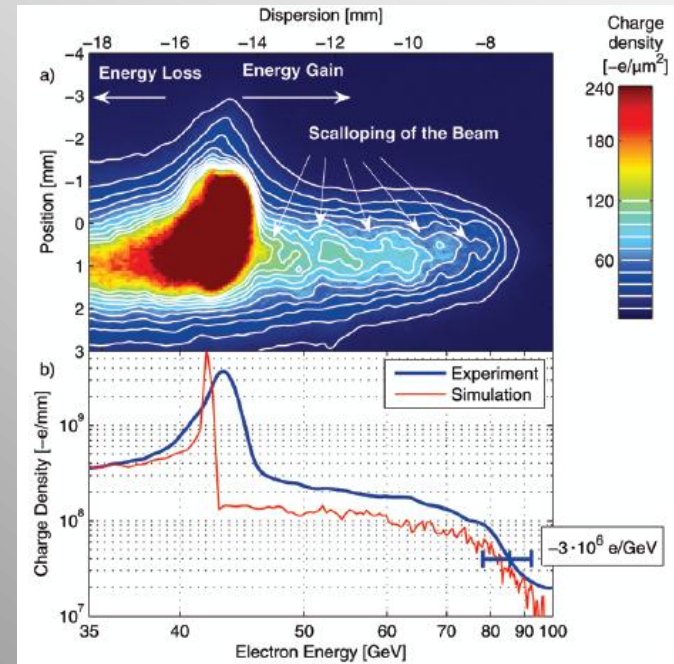
Patrick Muggli (USC)

Vitaly Yakimenko, Karl Kusche,

Marcus Babzien, Mikhail Fedurin (BNL/ATF)



N. H. Matlis, et al., *Nature Physics*, 2, 749 - 753 (2006)

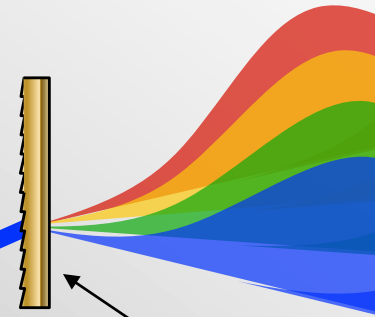
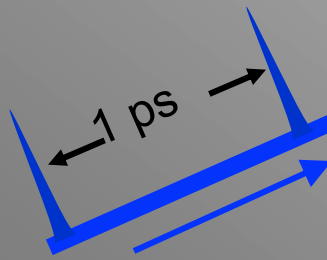
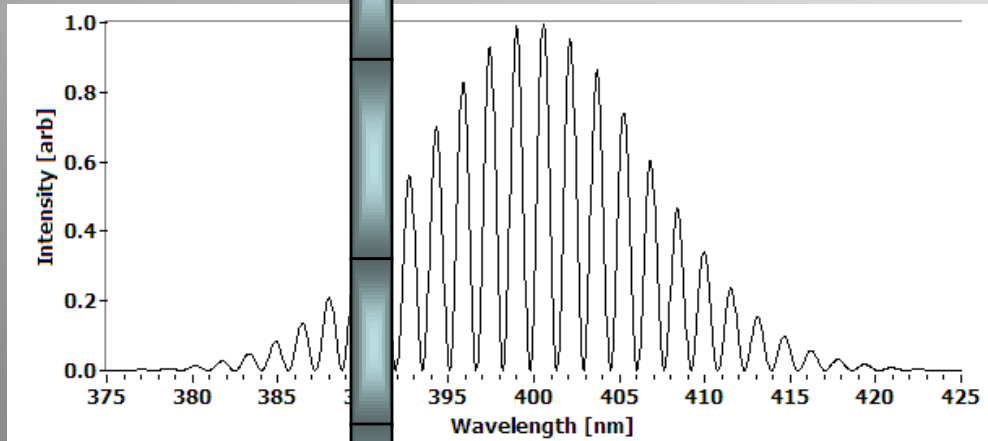


Blumenfeld et al., *Nature* 445, 741-744 (2007).

FDI: Temporal Overlap in Spectrometer

Interferogram

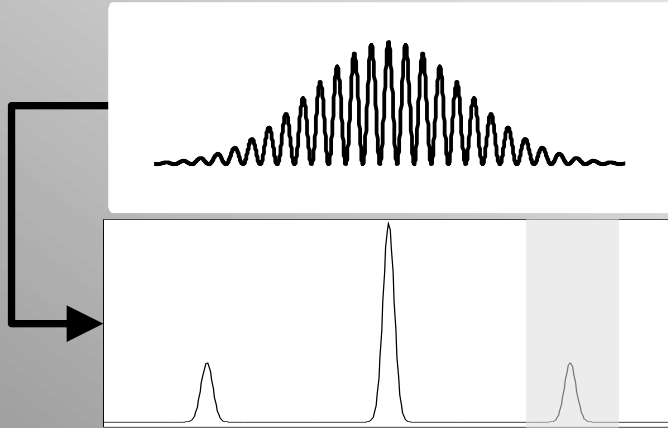
Spectrometer
CCD



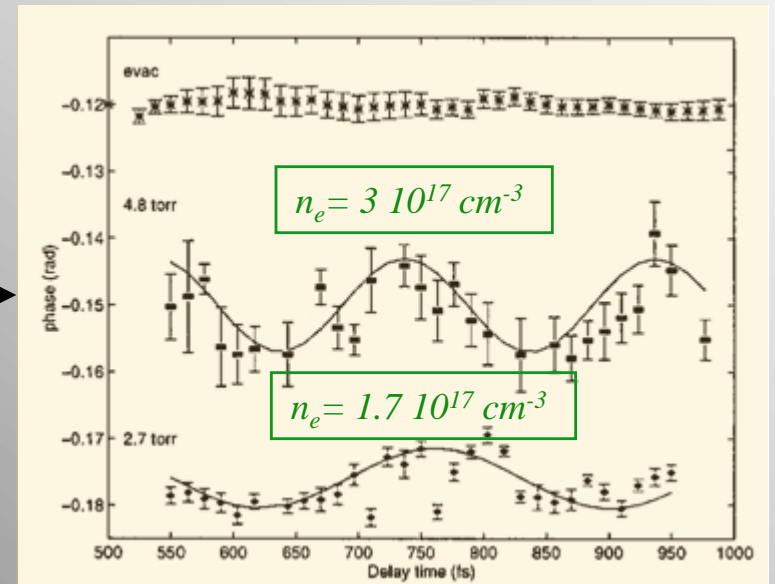
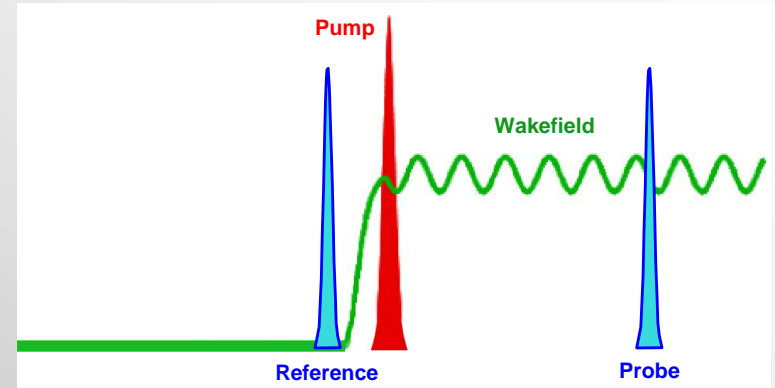
Spectrometer
Grating

Pulse Duration > Pulse Separation
PULSES OVERLAP!

FDI – Frequency Domain Interferometric reconstruction of laser-driven wakes

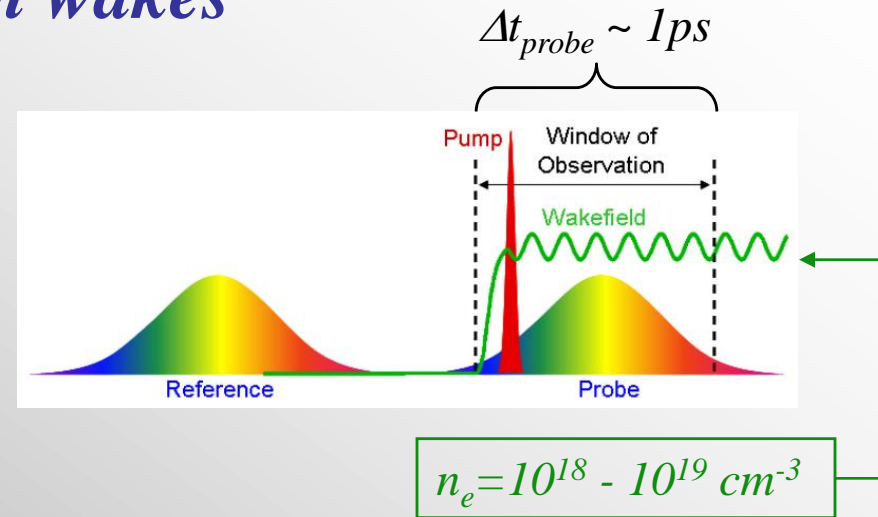
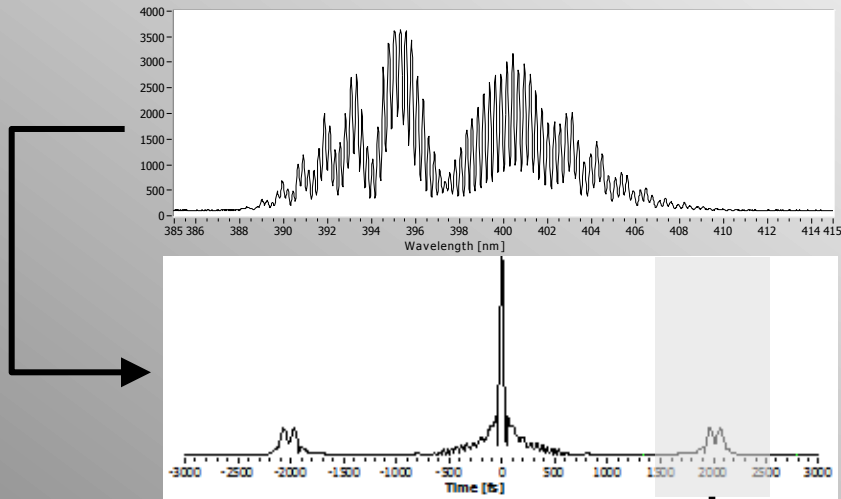


- *Multi shot*
- *Temporal and transverse resolution*
- *Very simple reconstruction*
- *Less sensitive to noise than FDH*
- *Requires good shot to shot repeatability of signal*

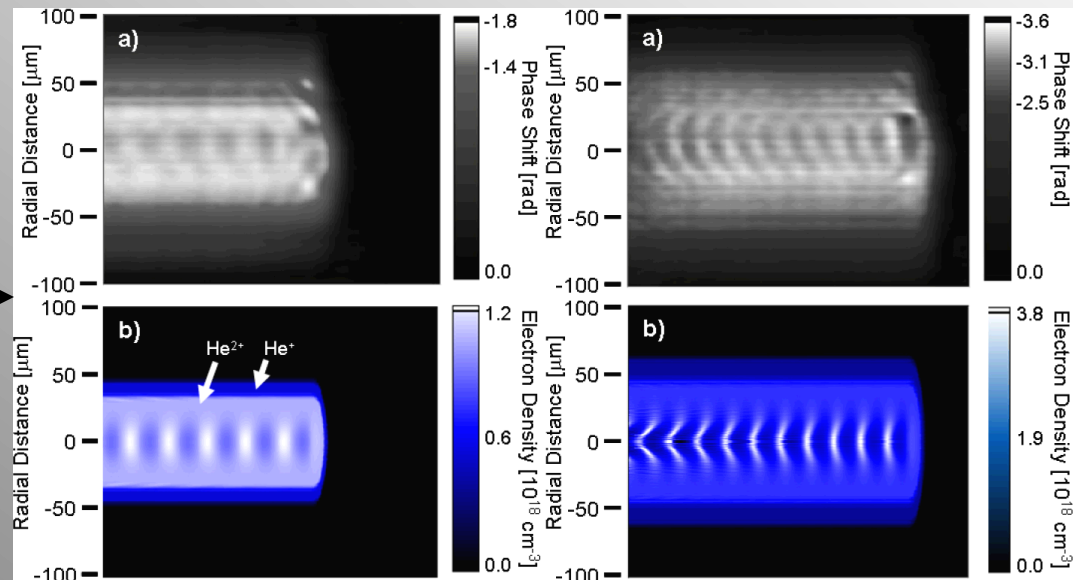


Tokunaga *et al.*, Optics Lett. **17**, 1131 (92)
Siders *et al.*, PRL **76**, 3570 (96)
Marqués *et al.*, PRL **78**, 3463(97)
Kotaki *et al.*, Phys. Plasmas **9**, 1392 (02)

FDH – Frequency Domain Holographic reconstruction of laser-driven wakes

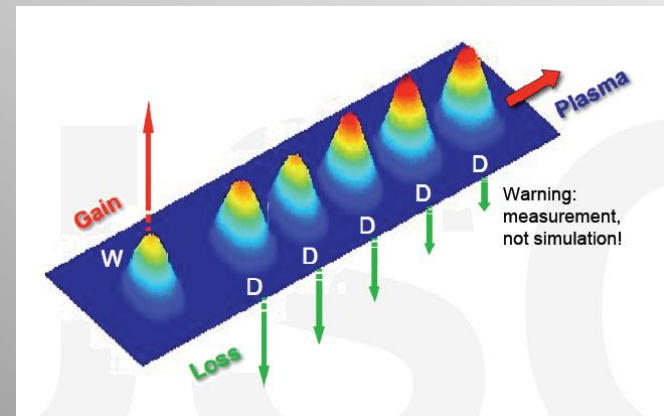
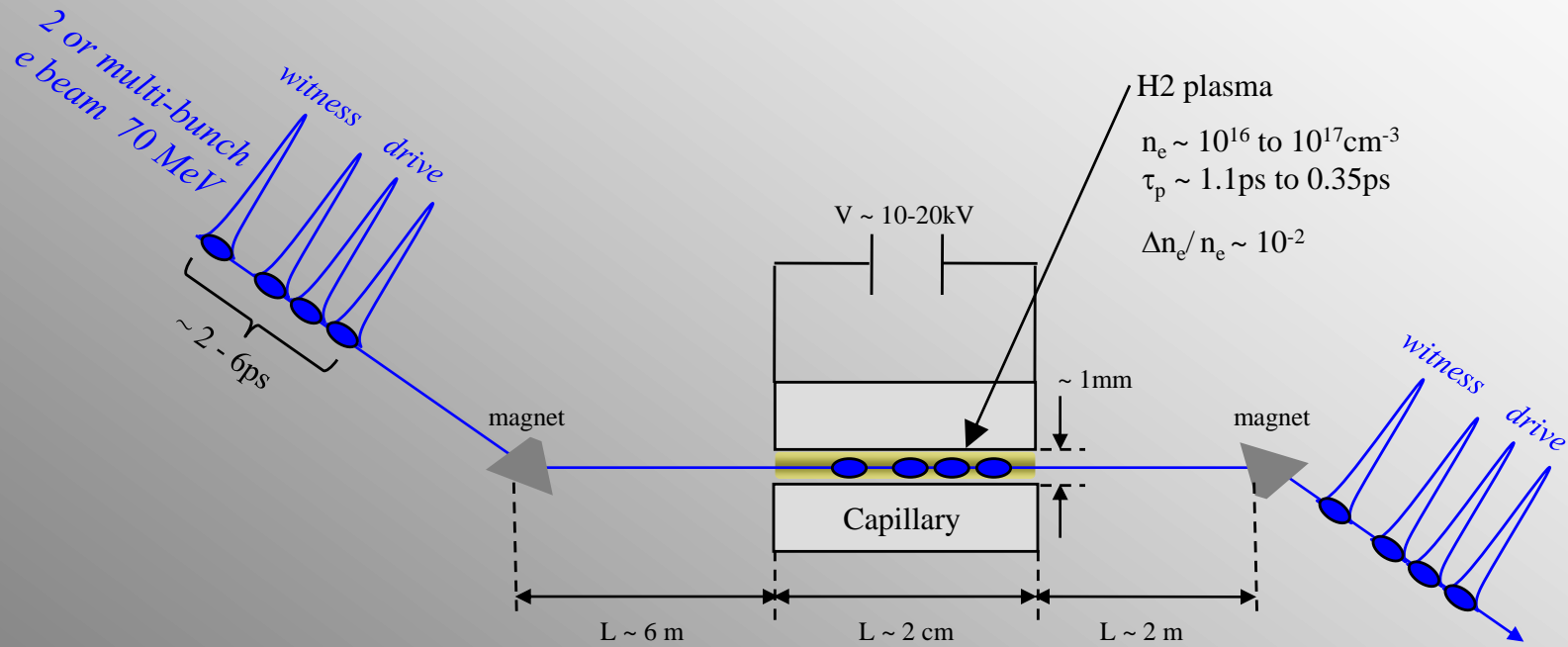


- Single shot
- Temporal and transverse resolution
- Signal to noise good for large n_e
- Prone to artifacts for low signal levels
 - Ionization front
 - Continuum generation
 - Second harmonic
 - Pixelation
 - Etc.



Parameters of BNL ATF experiment

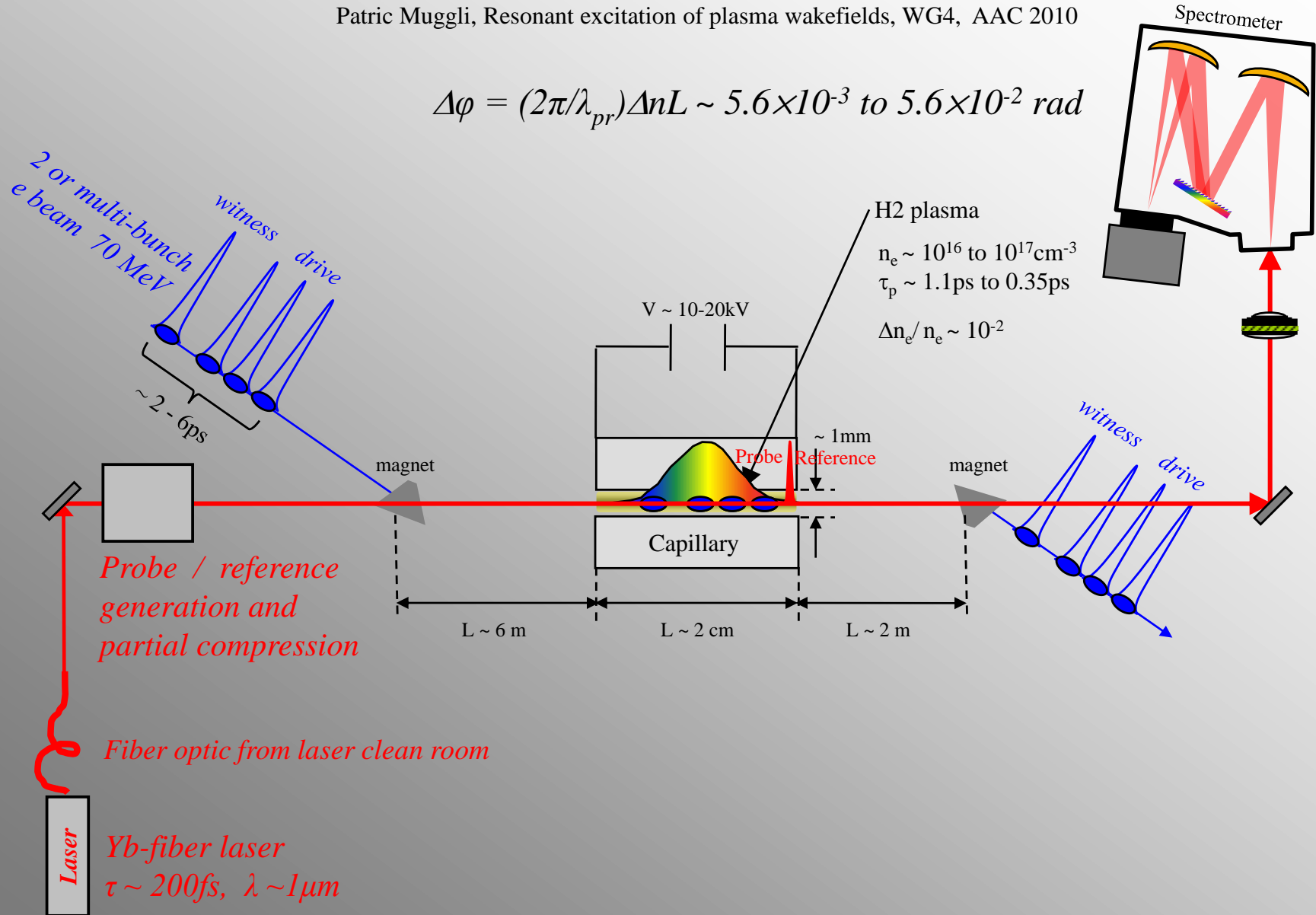
Patric Muggli, Resonant excitation of plasma wakefields, WG4, AAC 2010



Parameters of BNL ATF experiment with FDH

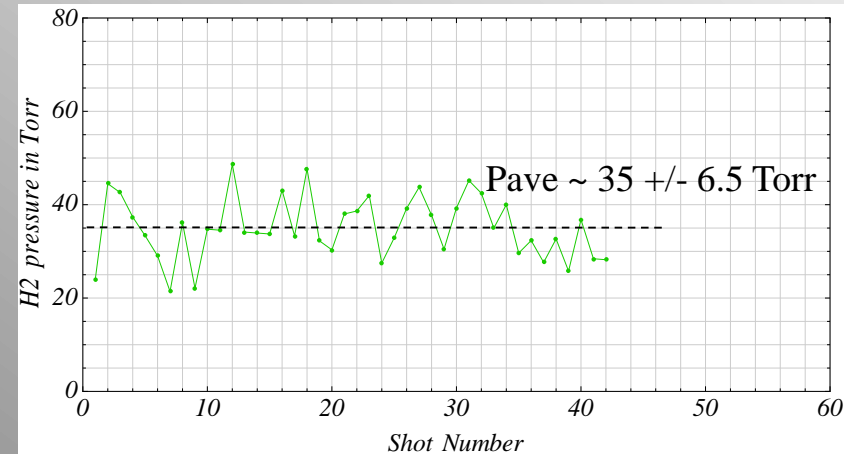
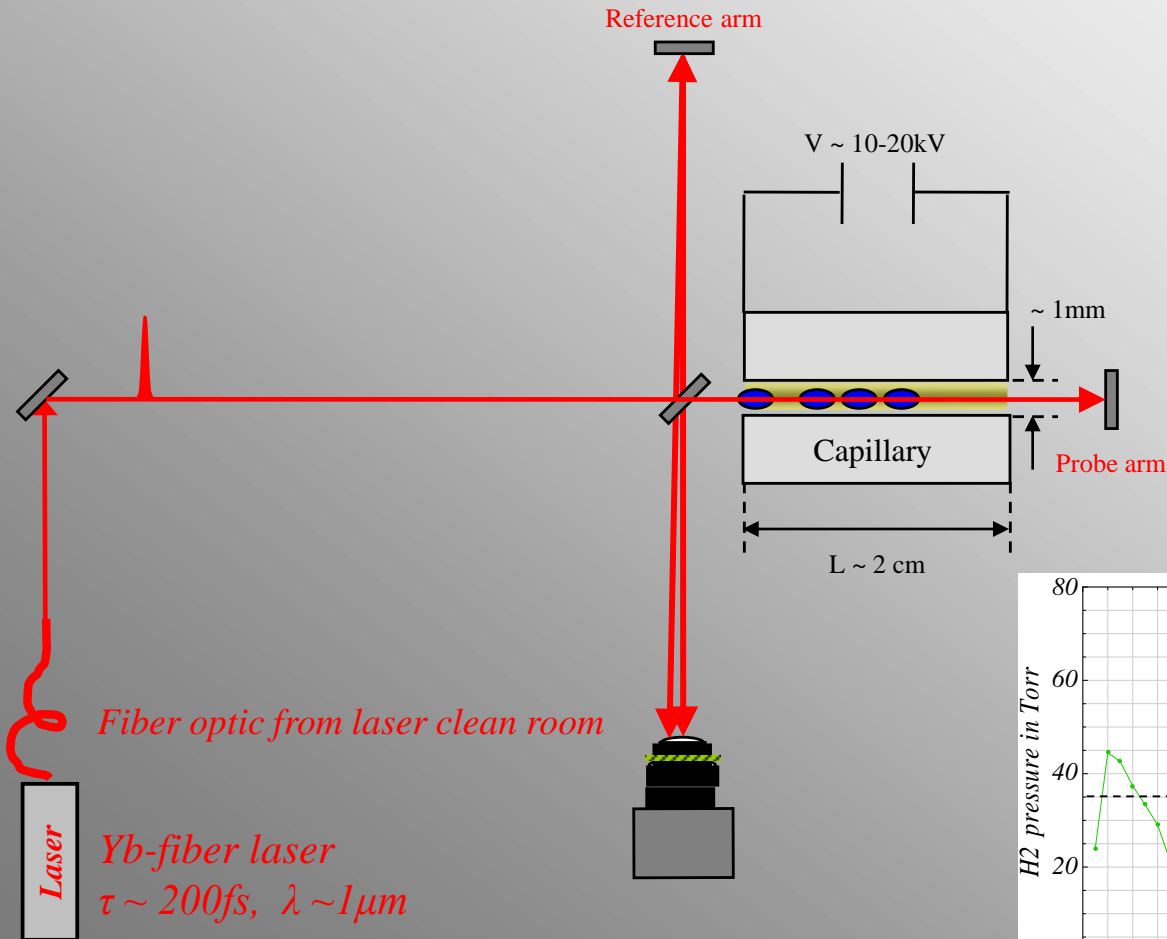
Patric Muggli, Resonant excitation of plasma wakefields, WG4, AAC 2010

$$\Delta\phi = (2\pi/\lambda_{pr})\Delta nL \sim 5.6 \times 10^{-3} \text{ to } 5.6 \times 10^{-2} \text{ rad}$$

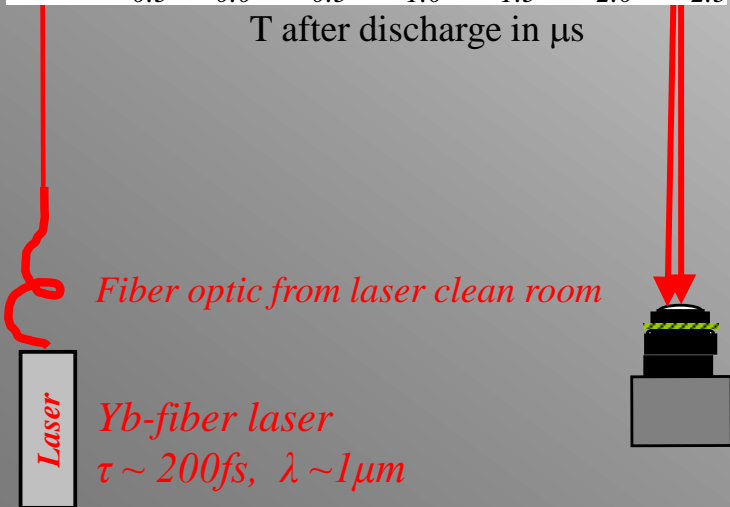
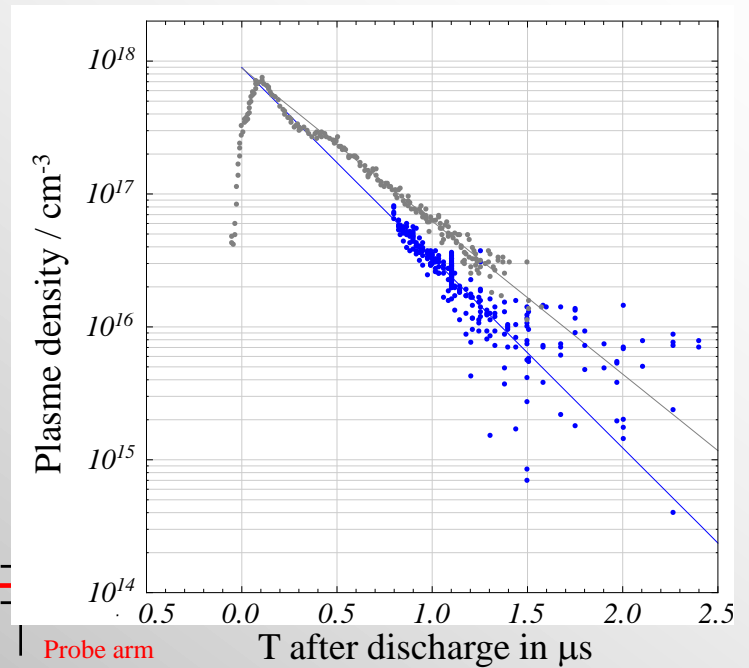
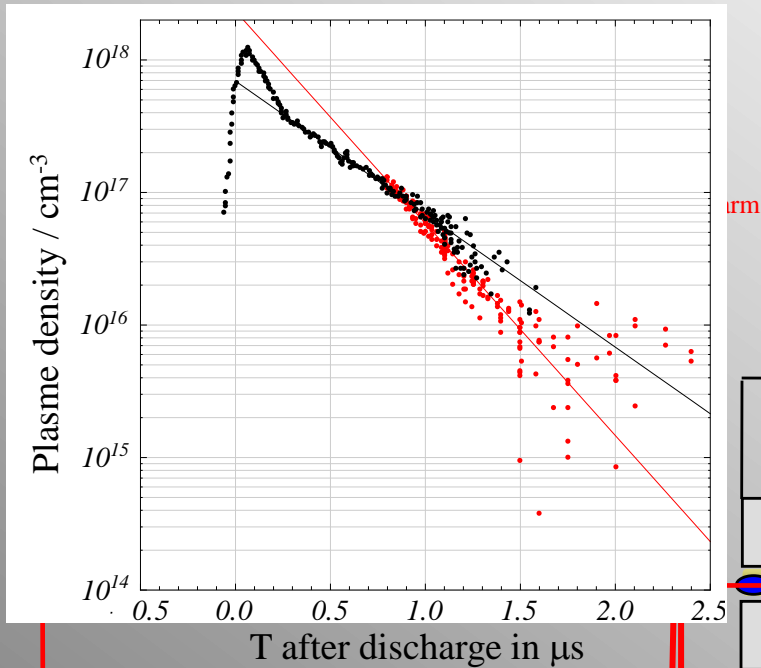


Capillary H₂ pressure and plasma density

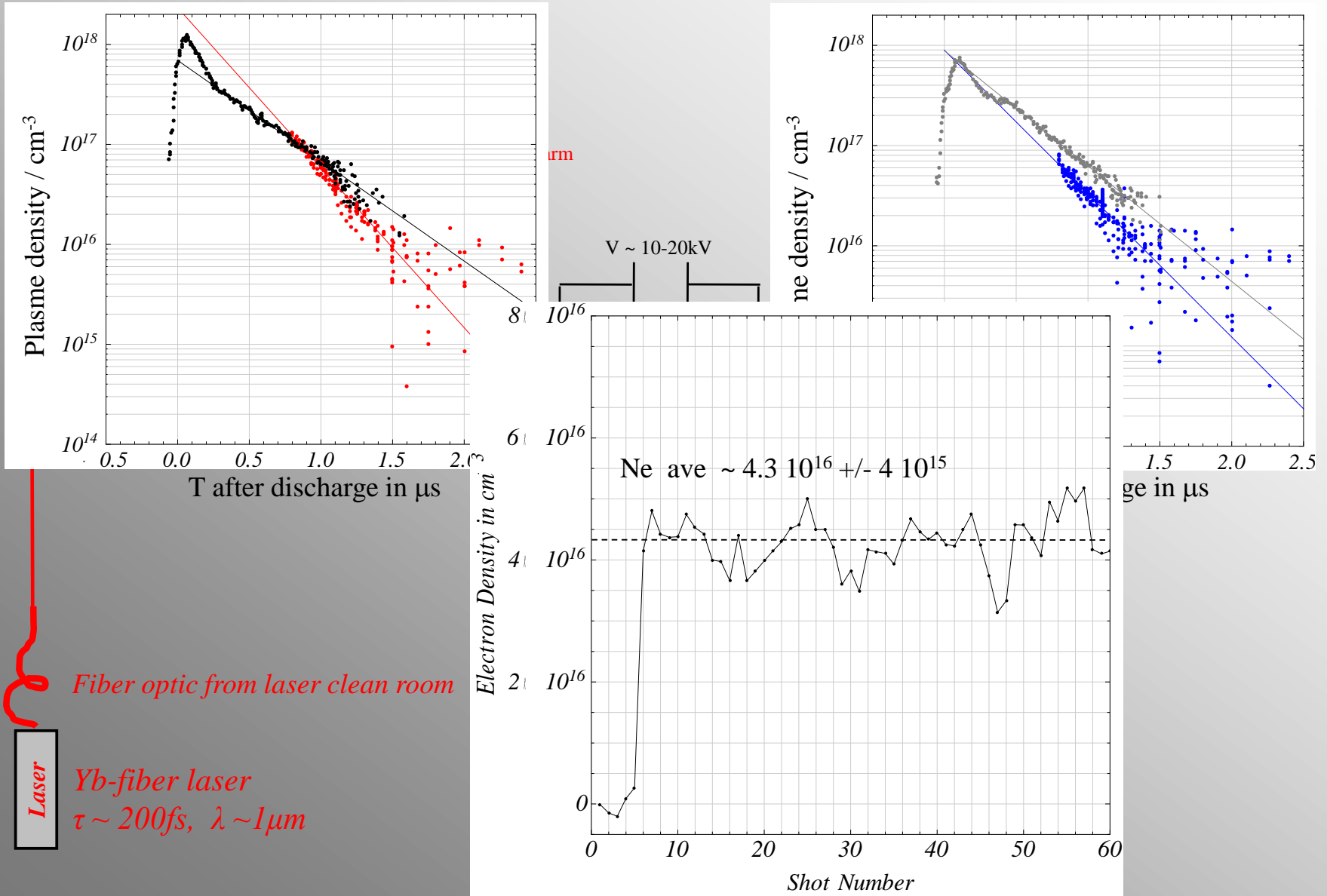
Patric Muggli, Resonant excitation of plasma wakefields, WG4, AAC 2010



Capillary H₂ pressure and plasma density



Capillary H2 pressure and plasma density

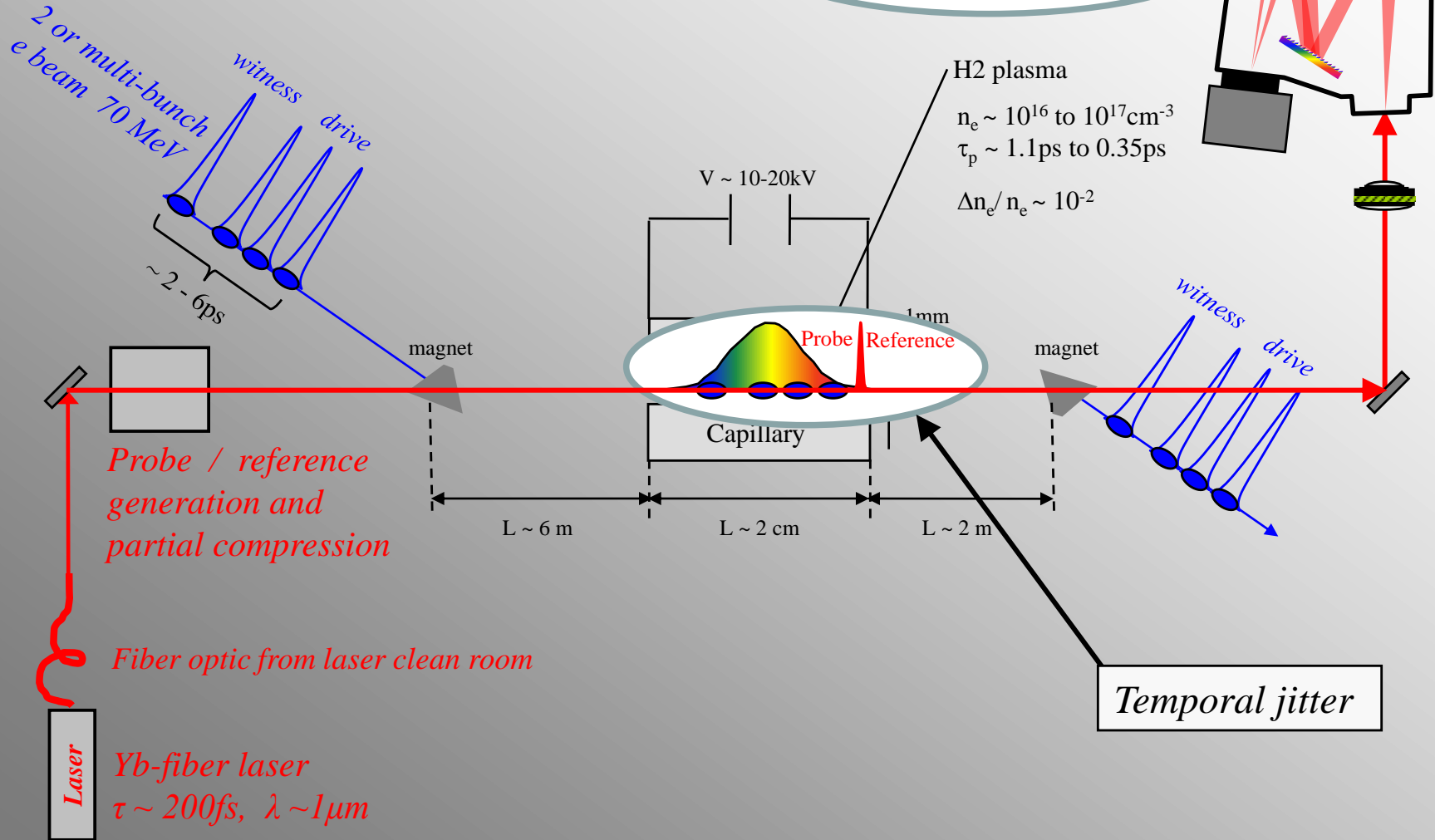


Possible issues

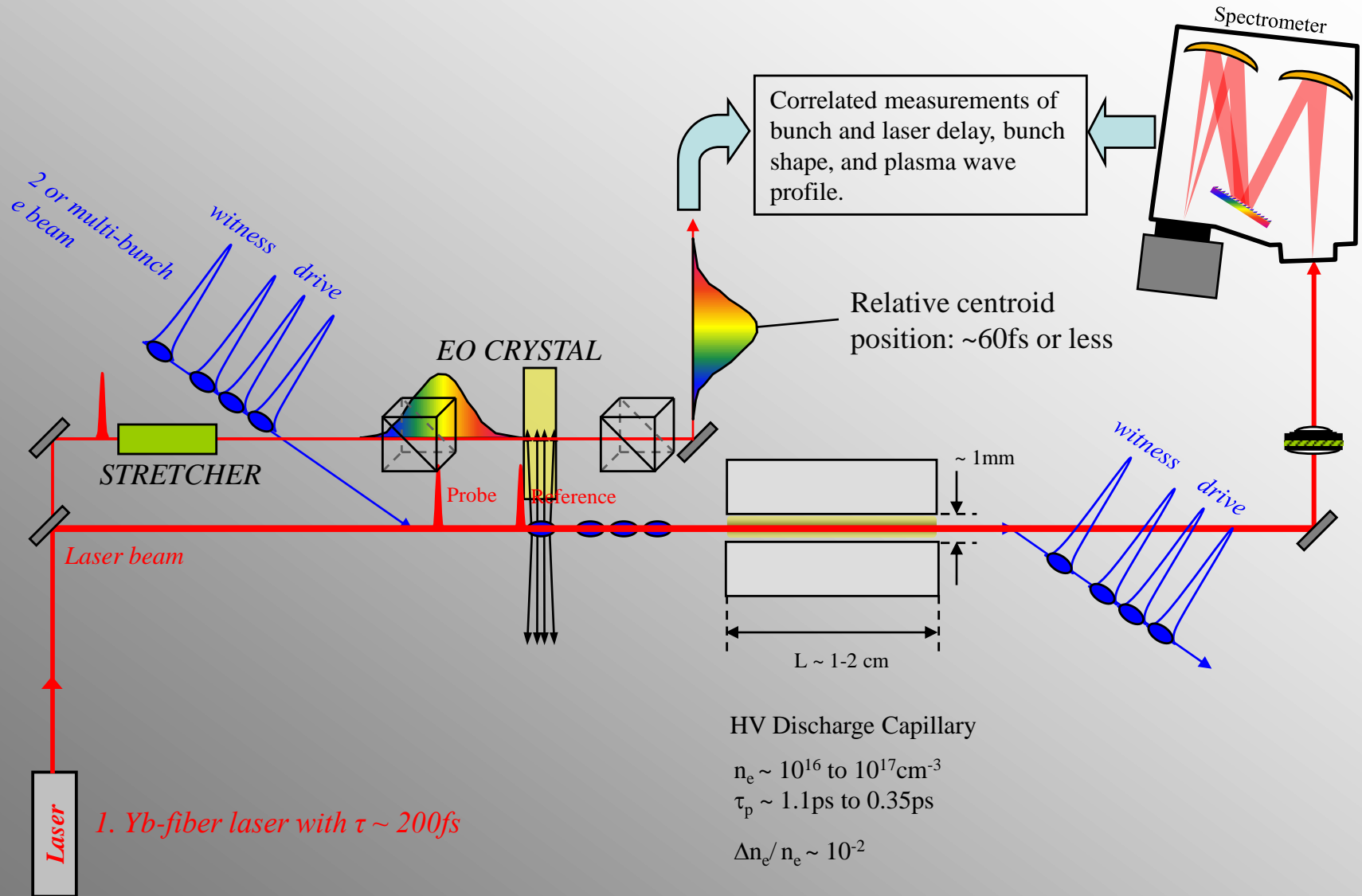
	$\Delta\phi$
Siders	$\sim 10^{-2}$ rad
Matlis	$\sim 10^{-1}$ rad
BNL	$\sim 10^{-3}$ rad

Small phase shifts

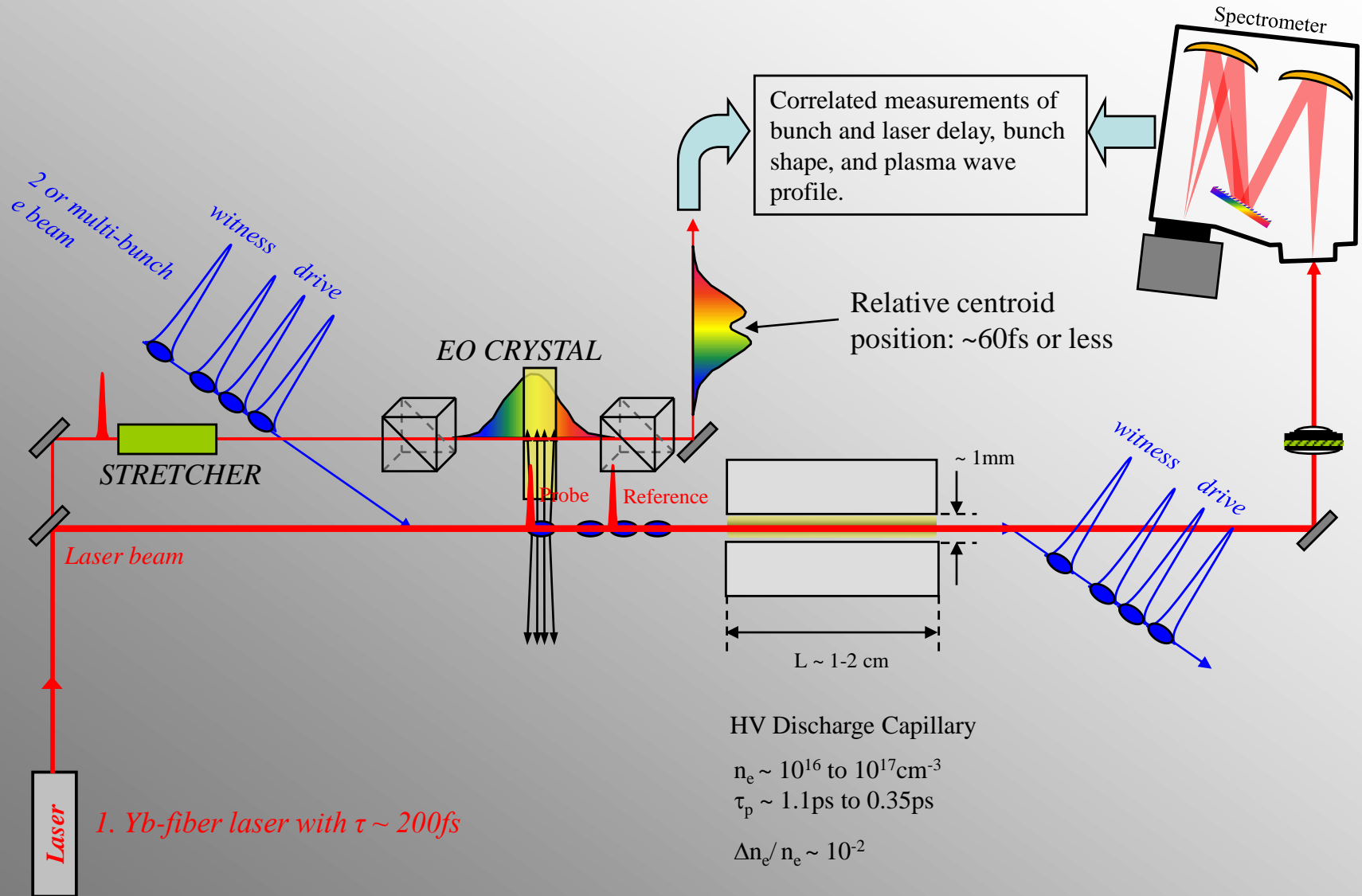
$$\Delta\phi = (2\pi/\lambda_{pr})\Delta nL \sim 5.6 \times 10^{-3} \text{ to } 5.6 \times 10^{-2} \text{ rad}$$



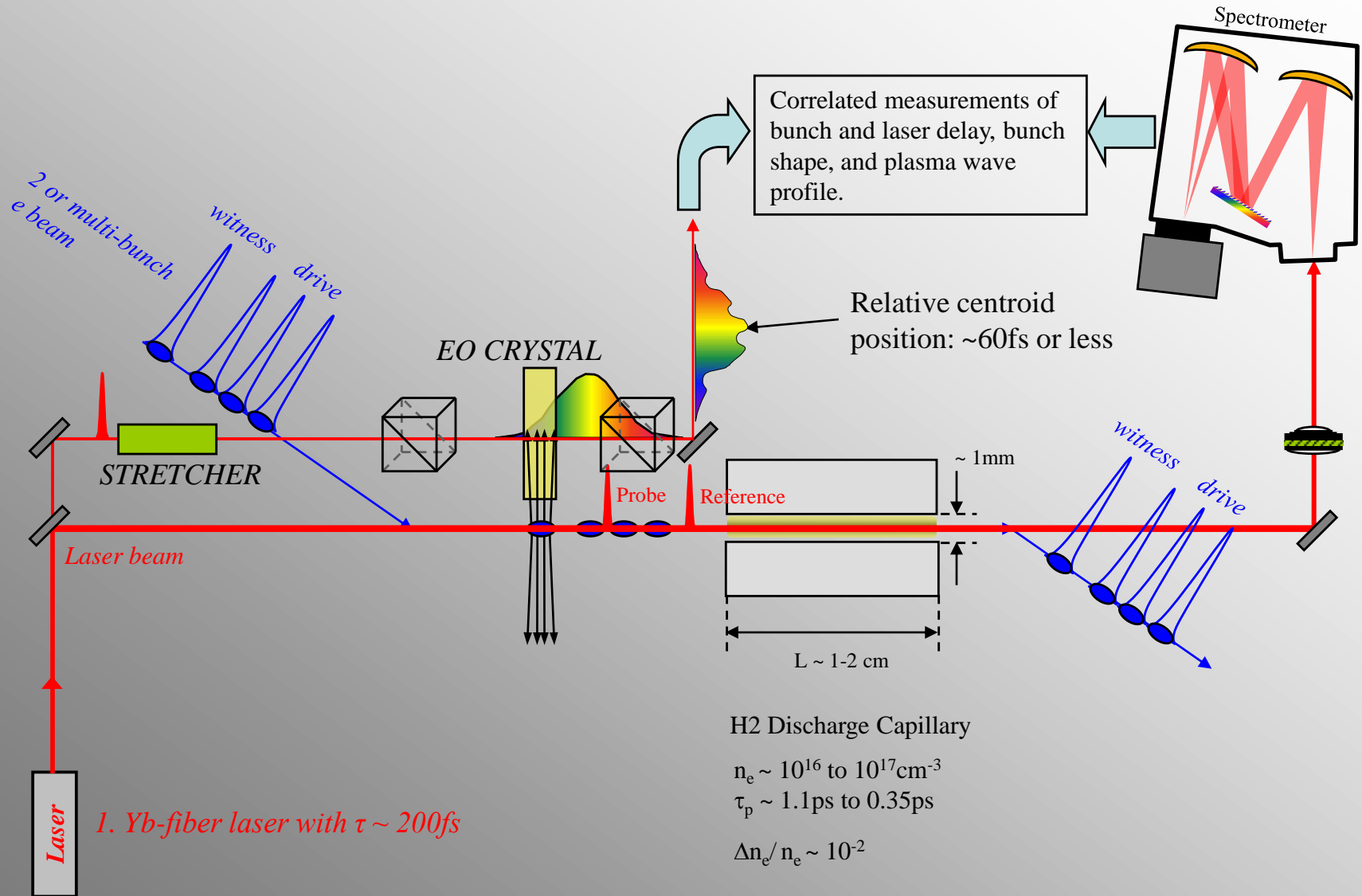
EO time delay and bunch shape measurement



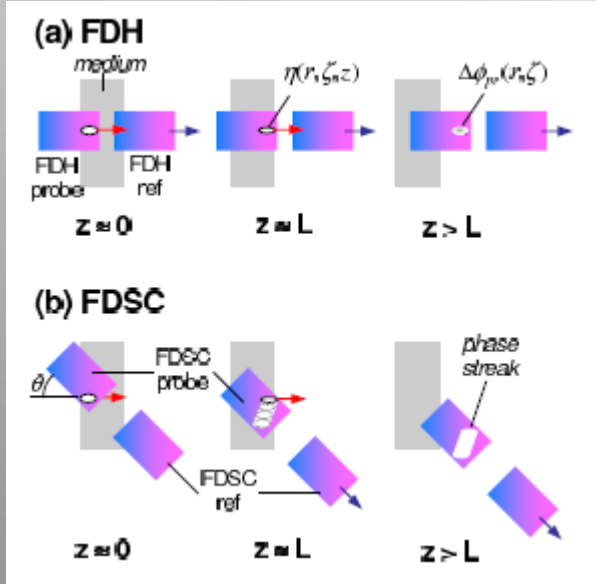
EO time delay and bunch shape measurement



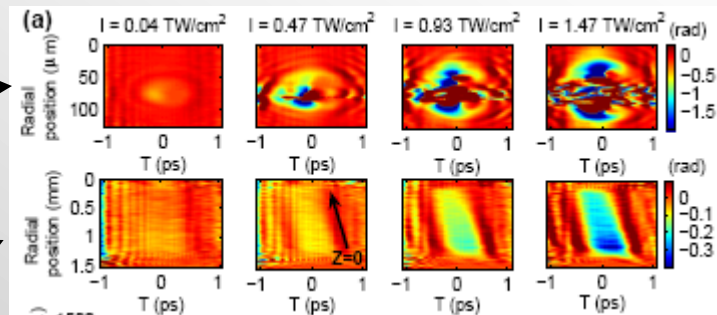
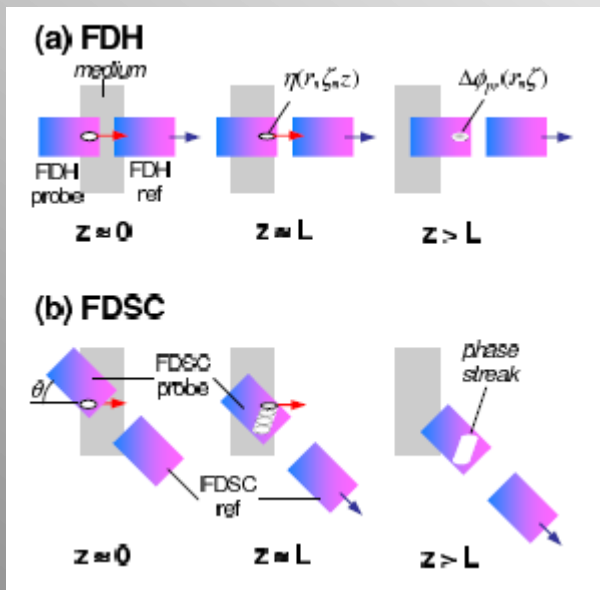
EO time delay and bunch shape measurement



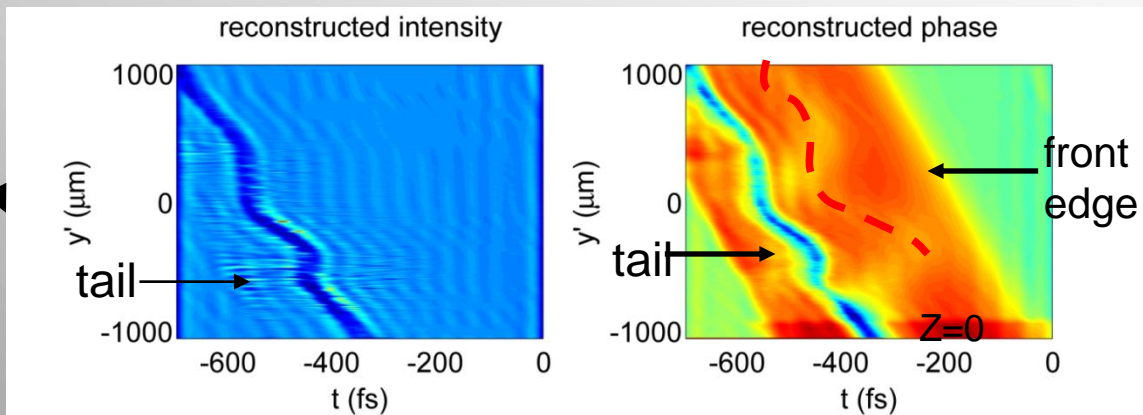
Frequency Domain Streak Camera



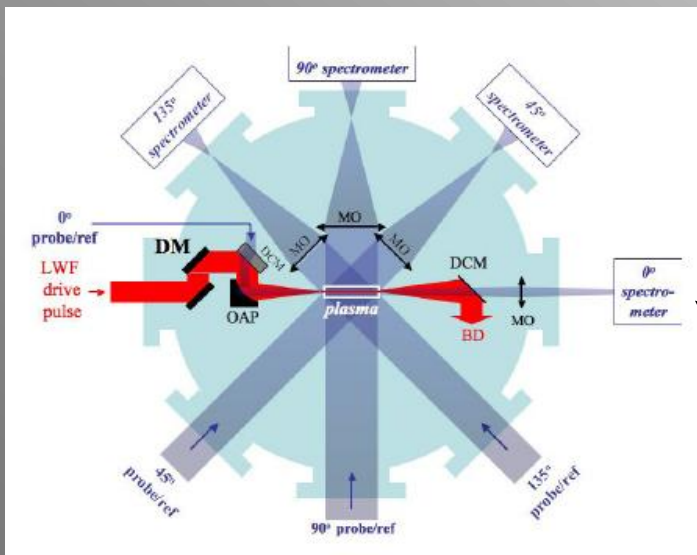
Frequency Domain Streak Camera



Zhengyan Li et al., WG1, AAC 2010

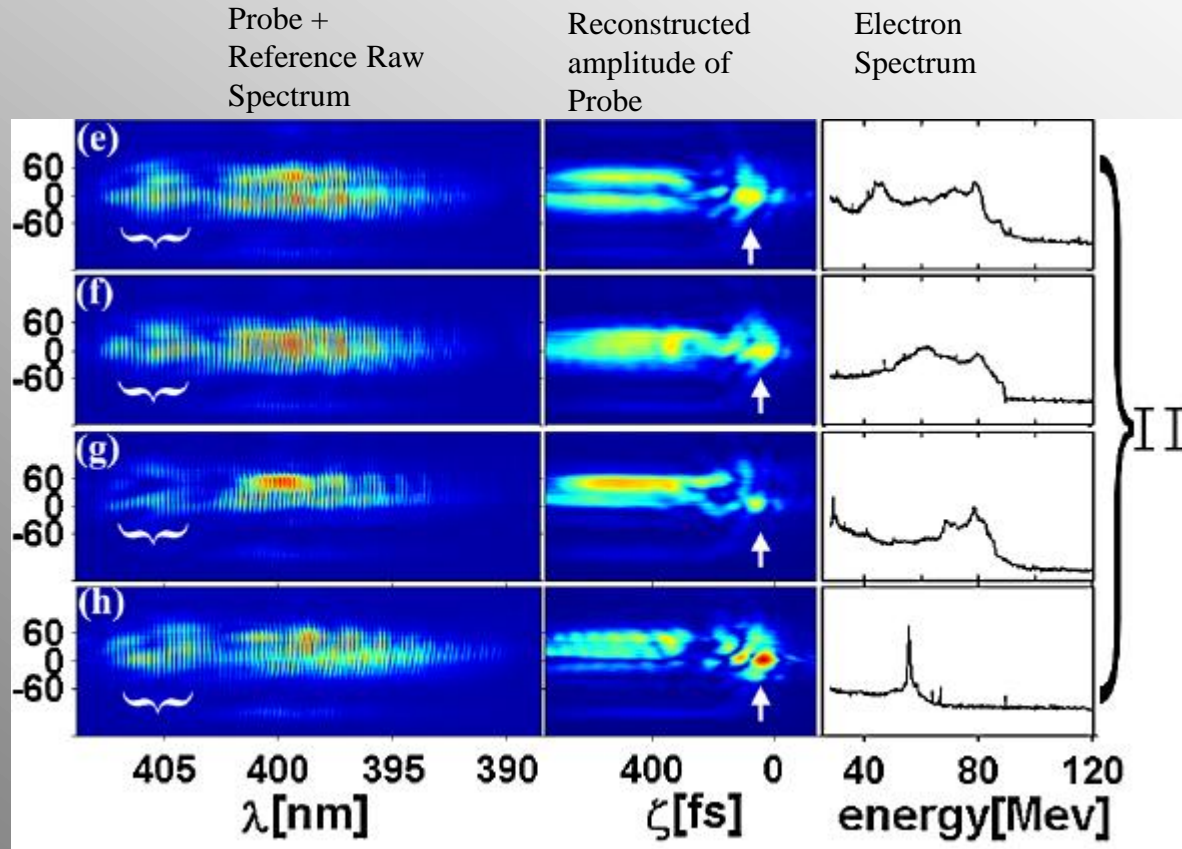


Simulation: Austin Yi, Gennady Shvets, UT Austin
See Xiaoming Wang et al., WG1, AAC 2010



Frequency Domain Tomography

Optical Bullets in the Blowout Regime



Conclusion

- *Direct measurement of plasma wave structure*
- *Initial FDI measurements, but probably FDH necessary*
- *Correlation of local plasma wave and microbunch amplitudes*
- *Direct observation of resonant wake enhancement in the multibunch experiments*

Looking Toward the Future: FACET

- *Direct observation of different structures of electron and positron driven wakes.*
- *Standard noninvasive diagnostic complementing particle diagnostics in next generation of PWFA experiments.*

